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UNITED STATES AIR FORCE SCHOOL OF AEROSPACE MEDICINE LASER INJURY GUIDEBOOK

John M. Gooch, Col, USAF, MC, CFS
Richard R. Harvey, Lt Col, USAF, MC, FS
U.S. Air Force School of Aerospace Medicine
Aerospace Medicine Consultation Division/FECO

Wanda Parham-Bruce, Lt Col, USAF, BSC
U.S. Air Force School of Aerospace Medicine
Aeromedical Research Department/FHC

Bret Z. Rogers, DAF
U.S. Air Force School of Aerospace Medicine
Occupational and Environmental Health Department/OEHH

Leon N. McLin Jr., DAF
711HPW/RHDO
4141 Petroleum Road
Ft. Sam Houston, TX 78234-2644

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Air Force Research Laboratory
711th Human Performance Wing
School of Aerospace Medicine
Aerospace Medicine Department
2510 Fifth St.
Wright-Patterson AFB, OH 45433-7913

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John M. Gooch, Col, USAF, MC, CFS
Richard R. Harvey, Lt Col, USAF, MC, FS
Wanda Parham-Bruce, Lt Col, USAF, BSC
Brett Z. Rogers, DAF
Leon N. McLin Jr., DAF

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14. ABSTRACT

The primary purpose of the laser injury guidebook is to provide guidelines and instructions for flight surgeons' interaction with potential laser beam exposures in aircrew and ground personnel. The intent is to provide an evaluation and initial management process to assess and respond to laser beam exposures of ocular and adnexal injury. Subjects covered in detail include the laser beam exposure threat in the HR aviation environment and the role of the flight surgeon in the management of laser beam exposures. Specifically, history, external examination, near visual acuity testing, far visual acuity testing, Amsler grid testing, pupils evaluation, stereopsis evaluation, color vision, slit lamp, dilation fundoscopy, and vitreoretinal hemorrhage are covered in detail. A point of contact list is provided as well as a suggested list of supplies and equipment. A laser beam incident questionnaire is included.

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Laser beam exposure, flight surgeon, aircrew, eye injury, corneal burn, retina

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1.0 INTRODUCTION

1.1 Purpose

This laser injury guidebook provides guidelines and instructions for flight surgeons responding to actual or potential laser beam exposures to aircrew and ground personnel. This guidebook will provide an evaluation and initial management process to assess and respond to laser beam exposures where ocular injury may have occurred.

1.1.1 Points of Contact. Appendix A provides a reference for points of contact for laser beam exposure incidents. All laser beam exposures resulting in flash blindness, persistent visual symptoms, or suspected eye injury shall be reported to the Tri-Service Laser Hotline referenced in the appendix.

1.1.2 Recommended Equipment and Supplies. Appendix B lists suggested equipment to help the flight surgeon assess a laser injury. Ideally, the near and distant visual acuity letter charts and the Amsler grid test referenced in this guide should be ordered from an appropriate source. The base optometry or ophthalmology clinic should be able to assist in identifying appropriate equipment. If needed, field charts and forms can be obtained via electronic mail from the Aerospace Ophthalmology Branch, Aerospace Medicine Consultation Division, U.S. Air Force School of Aerospace Medicine (USAFSAM) and printed on a laser printer.

1.2 General

1.2.1 The Threat. Laser beams represent a potential threat to mission effectiveness and flight safety. Laser-based systems and devices are proliferating and pose a threat to the eye, both temporarily and permanently, from friendly and hostile sources. Medical force protection and prevention in operational units should include training and awareness of the threat by direct flight surgeon involvement in flying safety and aircrew training programs. For example, awareness that many lasers, e.g., Class 1M (American National Standards Institute (ANSI) Z136.1-2007 or old ANSI Z136.1-2000 Class 2) and Class 2 (ANSI Z136.1-2007 or old ANSI Z136.1-2000 3A) pointers, although very bright, cause no more than momentary dazzle or temporary flash blindness effects may help reduce fear and anxiety associated with these events. On the other hand, more powerful lasers, to include laser pointers rated Class 2M (ANSI Z136.1 2007 or old ANSI Z136.1-2000 class 3B) or higher, are potentially dangerous, especially when the source is at close range. Laser beams can be invisible in the form of infrared (IR) and ultraviolet (UV) wavelengths. The risk of permanent ocular injury diminishes at increasing distances from the source. However, laser beam exposures may disrupt operations during critical phases of flight and have psychological effects at distances far beyond those associated with ocular damage (see Figure 1). Aircrew should be knowledgeable as to the entire laser beam threat spectrum, including appropriate steps to be taken upon exposure.

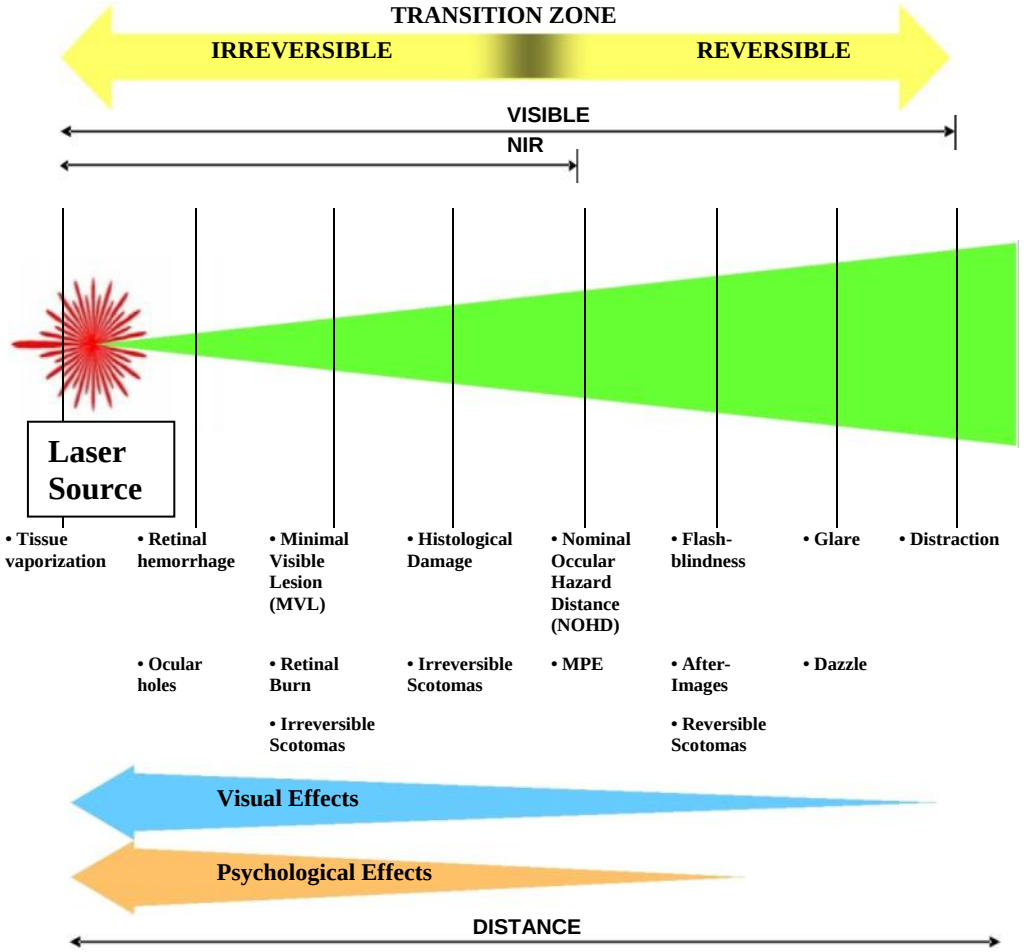


Figure 1. Ranges of Laser Bioeffects

1.2.2 Flight Surgeon. The key to evaluating and managing any laser eye injury or suspected laser beam exposure is immediate involvement of the local flight surgeon. The flight surgeon is responsible for coordinating and determining the appropriate care and action to be taken. The flight surgeon should approach a laser eye injury as a potentially serious injury. The diagnosis of a laser eye injury may be difficult since it may not produce any visible signs to the examiner. Subjective complaints may exist in the absence of objective physical findings. Personnel exposed or suspected to have been exposed should always be evaluated and managed in accordance with the appropriate service instructions and policies. Reference materials listed in this guidebook will provide additional knowledge and guidance. The Tri-Service **LASER INJURY HOTLINE (**1-800-473-3549, 937-938-3764/DSN 798-3764) is available "24/7" to answer any questions and should always be called in any laser beam exposure incident suspected of causing injury. Consultation on laser incidents is also available at USAFSAM through the hotline (937-938-3764/DSN 798-3764).

2.0 FLIGHT SURGEON EVALUATION OF EXPOSED CREWMEMBERS

2.1 History

Obtain a detailed operational and medical history as to the nature and characteristics of the laser beam exposure. Important details include characteristics such as intensity, color, constant or flicker nature of the light source, duration of exposure, location, estimated beam diameter, range, tracking, source, location (airborne or ground), glare, pain, photophobia, and any immediate or delayed symptoms. Some laser beams are invisible to the human eye (e.g., UV and IR) and may induce sudden visual symptoms. Be sure to record what types of personal protective equipment or viewing devices were being used. Past ocular and family eye histories should be included. Use of the Laser Incident Questionnaire (Appendix C) will aid in both the medical assessment and intelligence aspects of the incident. The Laser Incident Questionnaire will provide medical and laser experts with enough information to aid in initial treatment of exposed personnel. Involved personnel will undergo more extensive interviews by additional medical, operational, and military intelligence personnel.

Notifications as outlined in Attachment 4 of Air Force Occupational Safety and Health Standard 48-139 should be made as soon as possible. Field level notification should be made to the Deployed Medical Commander and the Air Expeditionary Wing Commander. Notify the Tri-Service Laser Injury Hotline (1-800-473-3549) as soon as time and circumstances permit.

2.2 External Examination

Perform an external examination of the skin and adnexa looking for burns or any evidence of physical trauma. Remember a UV or IR laser beam will be invisible to the naked eye but may result in visible external tissue damage. Photograph any abnormalities believed related to a laser beam exposure.

2.3 Near Visual Acuity Test

Near visual acuity should be tested at 14 inches using a standard Armed Forces Near Visual Acuity Chart card or equivalent. If available, this should be done with spectacle correction if required for reading. Always record visual acuity test results in each eye separately and whether the eye was corrected or uncorrected.

2.4 Far Visual Acuity Test

Distant vision should be tested using any standardized distant visual acuity tester. Ideally, this should be accomplished using spectacle correction, if required for vision. Generally, near and far visual acuity will correlate, but there can be wide variation, especially if correction is not used. If far visual acuity test results are worse than 20/30, or if corrective eyewear is not available, then administer a pinhole acuity test to assess far visual acuity. Always record visual acuity test results in each eye separately and state whether the eye was corrected or uncorrected. If not done at the standard 20-foot distance, or in an approved vision test apparatus, record the test distance and how it was determined.

2.5 Amsler Grid Test

The Amsler grid test provides information on the condition of the macula and perimacular region of the retina. An Amsler grid (provided in Appendix D) test should be administered with each eye separately at 30 cm under proper illumination and with corrective eyewear if required. Have the crewmember sketch out any abnormalities directly on the Amsler grid recording sheet. A defect on Amsler testing indicates that the central 20 degrees of the visual field may have been affected. The Amsler grid is capable of detecting scotomas and lesions as small as 50 microns and may reveal retinal damage not visible to the examiner. Not all laser eye injuries have an associated visible retinal lesion, and some visible retinal injuries may still present a normal grid test result. Document any changes related to a laser injury. The patient shall be re-examined as clinically indicated, ideally in 24 hours, but at least within 72 hours because expanding retinal damage effects may make detection of retinal damage easier.

2.6 Pupils

Examine the pupils for any change in shape, symmetry, reaction to light, or other abnormalities. Perform such examinations before administering dilating drops.

2.7 Stereopsis

Perform the Optec Vision Tester depth perception test if available. This testing should be performed with correction if required and before dilation. It is unlikely that stereopsis would be affected without other symptoms, but it should be checked before returning aircrew to flying duty.

2.8 Color Vision

Although it is unlikely that color vision will be affected in association with an acute event without other visible macular damage, it is possible that subtle effects may only be picked up with color vision testing. Color vision testing should be performed with each eye separately using an appropriate Cone Contrast Test (CCT). In the event a CCT is not available, a set of pseudoisochromatic plates, or PIP plates, should be utilized. The standard PIP I plates (Dvorine or Ishihara) screen for congenital red/green deficits; however, screening for acquired deficiencies, including blue/yellow, with the PIP II (SPP2) plates is desirable if this test is available to the flight surgeon. Color tests should be administered under approved illumination called Illuminant C or equivalent if available. Final results of this test should be included in the pass/fail assessment of the patient.

2.9 Slit Lamp

If available, a slit lamp examination should be performed on the anterior segment, cornea, anterior chamber, iris, and lens. Fluorescein should be used to examine for any corneal abrasions or burns. If a slit lamp is unavailable, use a Woods lamp or blue light source to examine the anterior portion of the eye. Describe, photograph, and diagram any lesions identified.

2.10 Retinal Examination

Retinal evaluations should be accomplished under dilated conditions if clinical circumstances warrant. It is recommended that both eyes be dilated even if only monocular symptoms are present. Proparacaine, tropicamide 1%, and phenylephrine 2.5% should be used as they last only 4-6 hours. Other dilating agents (such as Cyclogyl®, homatropine, or atropine) will have much longer effects. Using a direct ophthalmoscope, carefully examine the macular and paramacular region in both eyes and describe any abnormal lesions. Retinal lesions should be photographed, if possible, and digitally sent to the consulting ophthalmologist for evaluation and recommendations. In any suspected laser eye injury, the patient should be re-examined as clinically indicated, ideally in 24 hours, but at least within 72 hours because expanding retinal damage effects may make detection of retinal damage easier. The Laser Eye Injury Briefing and the Laser Incident Flow Chart (provided in Appendix E and Appendix F, respectively) can be used to manage patients following a laser incident.

2.10.1 Vitreoretinal Hemorrhage. The back of the eye should be evaluated for the presence of any hemorrhages. Such a hemorrhage may be localized or diffuse and may impair visualization of retinal details. The red reflex may be asymmetric and reduced in the affected eye. Such a scenario would be expected to be associated with a significant loss of visual acuity. Patients who are suspected of having vitreoretinal hemorrhage should be maintained at bed rest, with their head elevated to facilitate blood settling down and away from the macula. They should be evacuated to a referral ophthalmologist for more definitive care as soon as possible.

2.10.2 Chorioretinal Lesions. The classic hallmarks of significant laser beam eye injuries are chorioretinal burns and retinal hemorrhages. Chorioretinal burns can also be associated with inflammation throughout the eye. Usually this inflammation is not effectively treated with use of topical steroid drops because of poor penetration and access to retinal tissue. Therefore, oral or IV steroids are generally more effective in reducing intraocular inflammation but should only be considered in those cases consistent with a significant laser beam related retinal injury threatening the macula. Periocular, retrobulbar, or subconjuntival injections should only be given by an ophthalmologist. The flight surgeon, after consultation with an ophthalmologist, may be advised to administer IV or oral steroids if preservation of vision is thought to benefit from such therapy. Note: *The use of systemic steroids to facilitate preservation or recovery of vision should only be considered in confirmed or strongly suspected laser beam retinal injuries and only after consultation on a case-by-case basis with an ophthalmologist*.

2.11 Optical Coherence Tomography (OCT)

Use of OCT can be very beneficial to aid in the determination of subtle retinal effects from a laser beam exposure. OCT allows for examination of the nerve fiber layer, retinal pigment epithelium, and choriocapillaris. It has been used to demonstrate and document retinal injuries by lasers when no symptomatic changes have been present. It is unlikely the flight surgeon will have access to OCT outside an ophthalmic setting, but use of OCT imaging should be considered and requested if a laser beam injury is suspected.

APPENDIX A

Point of Contact Quick Reference

Point of Contact	Utilization
Tri-Service LASER Injury HOTLINE 1-800-473-3549 DSN 798-3764 Esoh.Service.Center@wpafb.af.mil (no classified data or material via e-mail) (encrypt any protected information)	Contact after laser beam exposure incidents suspected of causing injury. Available "24/7" by phone for treatment guidance and coordination of laser injuries. **The hotline can also be contacted at any time for information on laser training, safety issues, laser classification, etc.**
USAF School of Aerospace Medicine **Aerospace Ophthalmology Branch** (711 HPW/USAFSAM/FECO) 2510 Fifth Street, Bldg 840 Wright-Patterson AFB, OH 45433-7913 (937) 938-2675 DSN 798-2675	Provides ophthalmologic consultation. Assists in the coordination of evaluation and medical care of laser injuries. Broad base of medical expertise to include current evaluation techniques and treatment protocols. Provides training and support for AF flight surgeons, residents in aerospace medicine, ophthalmologists, and optometrists in aspects of laser evaluation and treatment. Responsible for the Laser Injury Guidebook. Can provide e-mailed evaluation charts, guidelines, and forms by special request.
USAF School of Aerospace Medicine **Radiation Health Branch** (711 HPW/USAFSAM/OEHH) 2510 Fifth Street, Bldg 840 Wright-Patterson AFB, OH 45433-7913 (937) 938-3764 DSN 798-3764	Maintains the Department of Defense Laser Injury Hotline. Provides laser safety consultation on operational issues. Coordinates follow-up on all laser exposure incidents after initial report to the hotline.
Air Force Research Laboratory/Optical Radiation Branch (711 HPW/RHDO) 4141 Petroleum Road, Bldg 3260 Fort Sam Houston, TX 78234-2644 (210) 539-8175 DSN 389-8175	Conducts hazard evaluations for operational lasers. Publishes and distributes evaluation tools such as the Laser Hazard Assessment software. Develops and recommends laser eye protection technologies. Performs world-class research into directed energy effects on living tissue and recommends ANSI safety standards.
Air Force Medical Support Agency **Radiation Protection Division** (AFMSA/SG3PB) 1500 Wilson Avenue, Rosslyn, VA 20332-7050 (703) 588-6338 DSN 425-6338	Primary policy and coordination agency for laser and optical radiation protection program. OPR for Air Force Occupational Safety and Health Standard 48-139. Provides guidance and policy to ensure effective implementation of the USAF health protection program for lasers and broadband optical radiation.

APPENDIX B

Recommended Equipment and Supplies

Below is a suggested list of equipment and supplies that the flight surgeon should find useful in evaluating laser beam exposure. The base optometry clinic should be able to assist in procuring many of the items that the flight surgeon might not already have. It is recommended that you have at least one blue or UV light source to evaluate the corneal surface with fluorescein.

Near and Far Visual Acuity Charts

- **Amsler grid tests**
- **Sodium fluorescein strips**
- **Artificial tears**
- **Sterile eye pads and bandage tape**
- **Proparacaine 0.5%**
- **Tropicamide 1%**
- **Phenylephrine 2.5%**
- **Topical ophthalmic antibiotic drops or ointment**
- **Pinhole occluder**
- **Penlight with detachable blue light filter**
- **Direct ophthalmoscope with blue light filter**
- **Woods lamp**
- **Pseudoisochromatic plates** (Armed Forces Color Plates, Ishihara, Dvorine, etc.)
- **Optec Vision Tester**
- **Color vision testing CCT device**

The following equipment is optional, but would be very useful if a high number of laser beam exposure cases are anticipated.

Digital Camera (for documenting external burns, lesions, etc.)

- **Hand-held Tonopen® and disposable tip covers**
- **Hand-held retinal camera**

APPENDIX C

Laser Incident Questionnaire

The following questions are designed to gather information to assist medical, operational, and intelligence personnel in analysis of laser beam exposure incidents. It should be anticipated that further questions and information will be sought as time allows. Finally, remember to call the Tri-Service Hotline at 1-800-473-3549 or DSN798-3764 as soon as possible.

1. Describe the light you saw

What color(s) was the light(s)?

How bright was it?

How long was it on?

Was it uniform in appearance?

Did the intensity of the light change?

Was it constant or did it pulse or flicker? If so, how fast did it pulse or flicker?

How wide (perhaps using finger widths at arm's length) was the beam at origin?

How wide on exposure was the light? Did the light fill your cockpit or compartment?

Was the light emanating directly from a source or was it reflected off a surface?

Were there any other unusual light sources?

Have you seen this light(s) before?

2. Date, location, and circumstances

a. Date and time (local & Zulu using a 24-hour clock) that the exposure occurred.

local: DDMMYYYY hh:mm
Zulu: DDMMYYYY hh:mm

b. Location of exposure (if nonclassified). Describe location preferably using degrees decimal (DD), degrees-minutes-seconds (DMS), Universal Transverse Mercator (UTM), or Military Grid Reference System (MGRS).

c. How far and in what direction was the light source? Was it airborne or surface based?

d. What was between the light source and your eyes?

e. What were the atmospheric conditions: clear, overcast, rainy, foggy, hazy, and sunny?

f. Was any equipment such as windscreens, visors, NVGs, goggles or sensors affected by the light?

g. What evasive maneuvers did you attempt and did the beam follow you as you tried to move away?

3. Effects

a. How long did you look into the light beam?

b. Did you look straight into the light beam or off to the side?

c. What tasks were you doing when the exposure occurred? Did the light(s) hamper you from doing those tasks?

d. Were both eyes exposed? If not, describe the difference between the light exposure (for example, one eye was shielded or closed, or on the side away from the light beam). Describe any difference in the effect on either eye.

e. Was the light so bright that you had to blink or squint, close your eyes, or look away? Was the light painful? Describe the pain. For how long did the pain persist after the light exposure?

f. Was vision affected while the light was on? How much of your visual field was affected? What types of things could you see or not see? Did you notice the color of instruments or targets change? Did the changes to your vision remain constant or vary during the exposure? If the light source was mounted on a platform (e.g., aircraft, ground vehicle, or building), how much of the platform was obscured?

g. Did your vision remain affected after the light was extinguished? If so, for how long and how did you estimate the time? What types of things could you see or not see? Did you notice afterimages (“spots before your eyes”)? If so, describe them.

h. Were there any lingering (i.e., hours or days) visual effects? If so, were the effects continuous or intermittent? Did you have problems reading or seeing in low-light conditions? How long until you were able to see normally again?

i. Did you notice any reddening, warming, or burns to your skin?

j. Describe the condition of your vision before the incident. Do you wear glasses?

k. Are you taking any medications?

LASER RADIATION ACCIDENT/INCIDENT REPORTING FORM

1. MEDICAL PROVIDER CONTACT INFORMATION:	
NAME/RANK	ORG/INSTALLATION
EMAIL	TEL
2. PATIENT INFORMATION Army__ Air Force__ Navy__ Marine Corps__	
NAME:	FLIGHT STATUS/DUTY STATUS:
ORG/INSTALLATION:	PHONE NUMBER:
ADDRESS:	EMAIL:
3. LASER ACCIDENT / INCIDENT INFORMATION	
LOCATION OF ACCIDENT/INCIDENT:	DATE/TIME:
NAME/DESCRIPTION OF LASER:	
EXPOSURE DISTANCE (meters):	EXPOSURE DURATION (seconds):
BRIEF DESCRIPTION OF ACCIDENT/INCIDENT:	
TYPE OF EXPOSURE: ☐ Intra-beam ☐ Reflection	FLASH BLINDNESS/DURATION?:
WERE OPTICAL INSTRUMENTS USED? ☐ Yes ☐ No	
WAS LASER EYE PROTECTION WORN? ☐ Yes ☐ No	TYPE:
MEDICAL FINDINGS	Document Visual Acuity, Amsler Grid, Stereopsis, Color Vision, External Exam, Slit Lamp, Internal Exam, and Optical Coherence Tomography (if available)

Note to Medical Examiners: If abnormalities are found, please send encrypted SF 600 or AHLTA Note.

USAFSAM/OEHT: ESOH SERVICE CENTER: esoh.service.center@wpafb.af.mil, 1-800-473-3549 DSN: 798-3764
Authority for the laser injury hotline is derived from DoDI 6055.15

INSTRUCTIONS

NOTE FOR CODING: Use E-926.4 for illumination without retinal damage or E-997.0 for illumination with retinal damage. Every Incident involving an alleged or suspected overexposure to laser radiation will be investigated and evidence of overexposure or injury (or absence thereof) documented in accordance with own service policies and directives:

Army: USAHPSA/SGPS-PSP-40

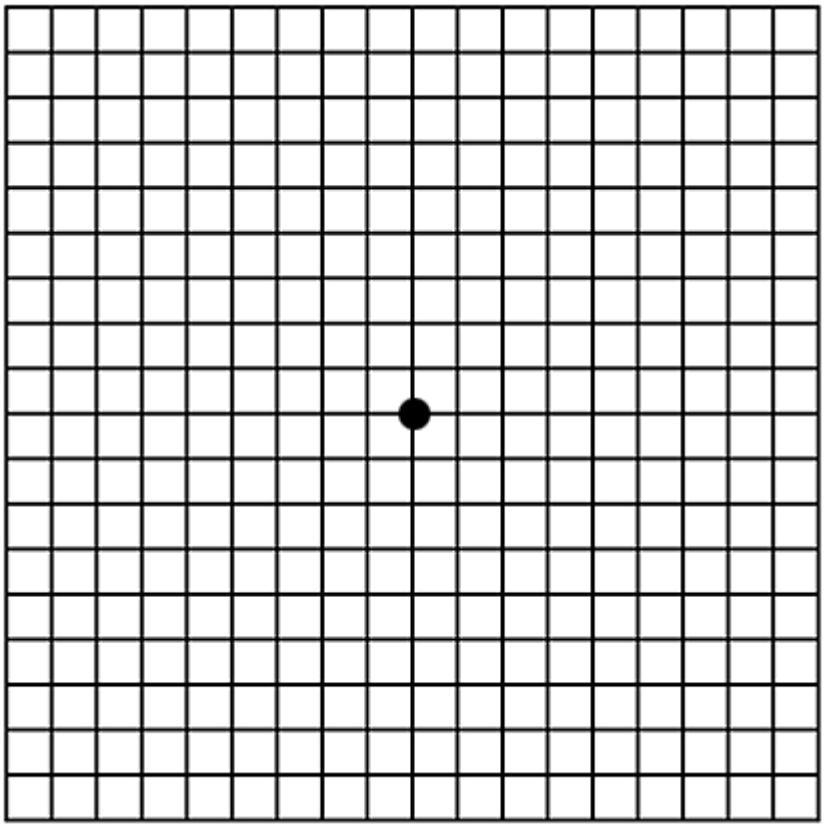
Air Force: AFOSH 48-139

Navy/Marine Corps: OPNAVINST 5100.27B/MCO 5104.1C and BUMEDINST. 6470.23

Note: An electronic copy of this form can be found at https://kx.afms.mil/esoh or requested from the hotline. Additional sheets (narratives, exams, etc.) may be attached as appropriate.

APPENDIX D

Amsler Grid Test



Instructions

1. Have airman wear his/her glasses or correction (unless patient indicates his/her correction is solely for distance only).
2. To test right eye, begin by covering left eye.
3. Hold the sheet 30 cm from your eye (about 2 cm longer than this sheet length).
4. Ask patient what is in the center of the page (failure to see central dot may indicate central scotoma, so it's important to ask this question before telling patient to focus on the central dot).
5. Ask patient if all four corners of the diagram are visible.
6. Focus on intersection of the lines inside the center dot.
7. While looking at the center, do you notice any dark, hazy, or missing areas on the grid?
8. While looking at the center, do you see all the horizontal lines? All the vertical lines?
9. Do all the lines appear straight?
10. Repeat test for left eye

If airman wears glasses, then indicate what for and if glasses or contacts lenses were worn during the test.

APPENDIX E

Laser Eye Injury Briefing

The following guide is for the flight surgeon to use to brief aircrew following a laser incident.

Direct laser exposures will appear very bright and can be quite alarming, even at exposure levels incapable of causing damage. Aircrew members need reassurance once eye injury has been ruled out that they have not sustained any damage and the laser illumination will not result in development of damage in the future.

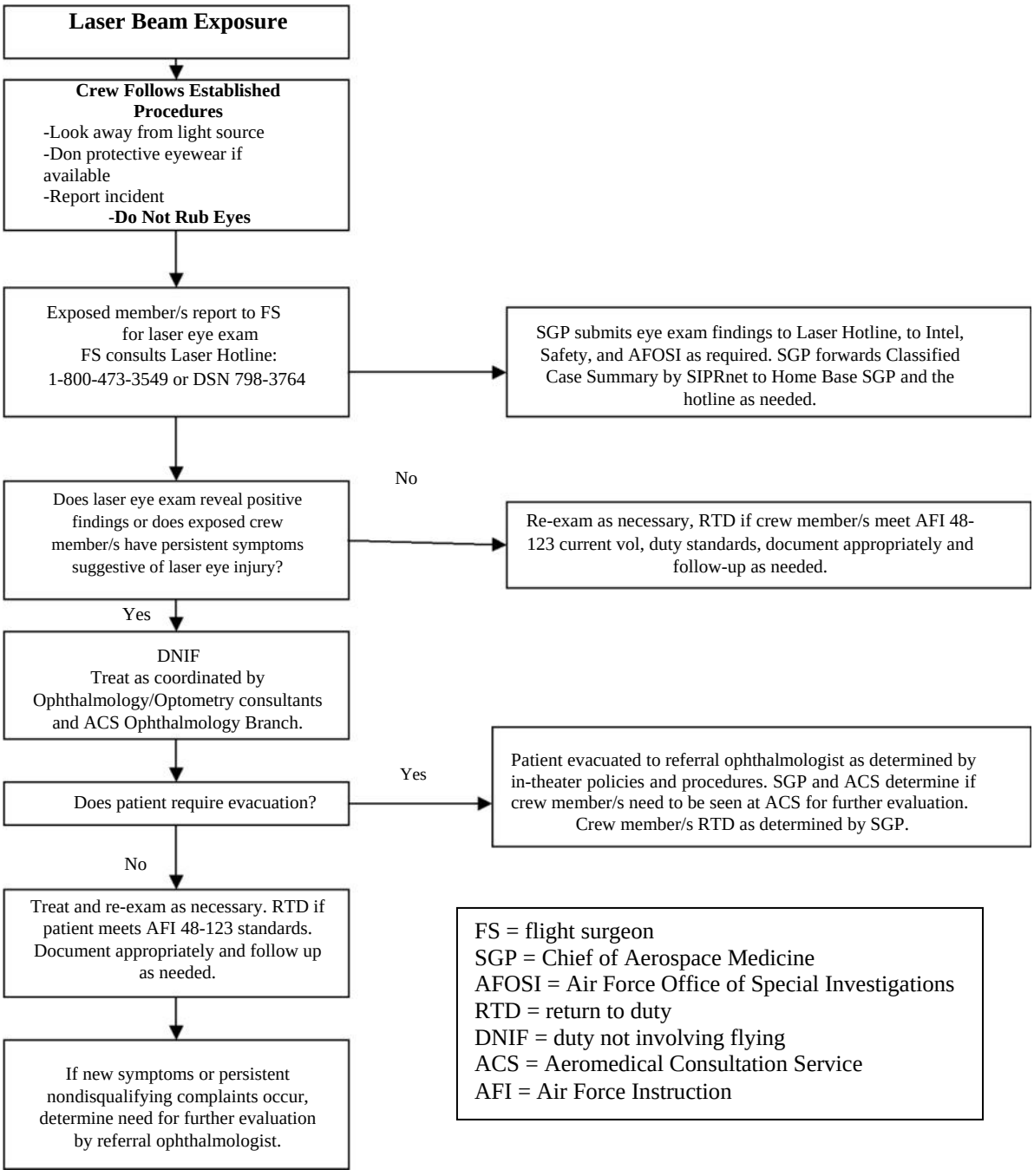
If the ocular examination is normal, visual acuity is good, Amsler grid is normal, and there are no persistent symptoms of injury, the following observations should be related to the aircrew member:

> There is no evidence of any damage from this laser illumination. During the examination, you read 20/20 size letters and there was no distortion on the Amsler grid test. Your retina, cornea, and lens appear normal and there is no evidence of injury. Most people, after encountering a laser incident, quite naturally start to feel very conscious about how their eyes feel and sometimes rub their eyes. Rubbing your eye may produce small scratches on the cornea that result in a painful irritated eye. Eye rubbing should be avoided.
>
> Lasers can be the source of eye injuries, but they must have sufficient energy. No damage was detected by the testing we performed. However, if you have any symptoms or concerns, another examination should be accomplished at the earliest opportunity.

If the examination reveals positive findings and/or there are persistent symptoms suggestive of laser injury, the aircrew member should be informed. Disposition and treatment should be coordinated with ophthalmology/optometry and the Aeromedical Consultation Service ophthalmology staff.

APPENDIX F

Laser Incident Flow Chart



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LIST OF ABBREVIATIONS AND ACRONYMS

ANSI	American National Standards Institute
CCT	Cone Contrast Test
IR	infrared
OCT	optical coherence tomography
PIP	pseudoisochromatic plates
USAFSAM	United States Air Force School of Aerospace Medicine
UV	ultraviolet